169

INSTRUCTION MANUAL

for

MODEL RH-10

WWV

STANDARD FREQUENCY CALIBRATOR

BROWNING LABORATORIES, INC.
WINCHESTER, MASS., U.S.A.

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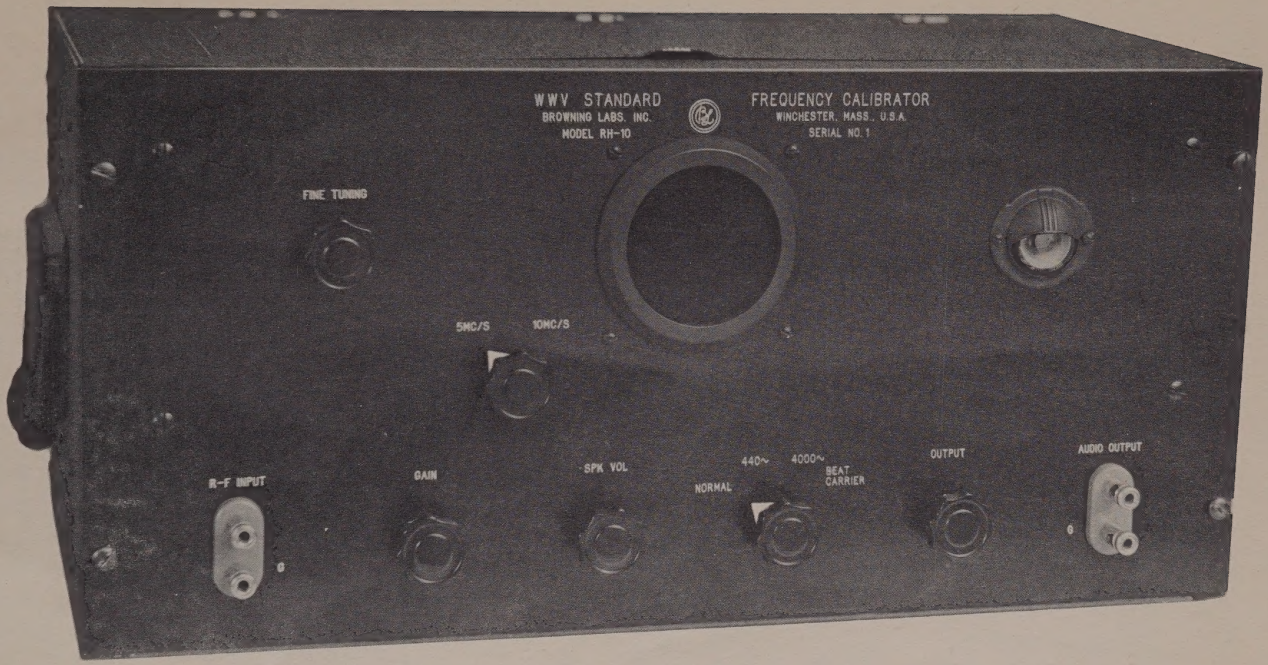

WWV STANDARD
BROWNING LABS. INC.
MODEL RH-10
FREQUENCY CALIBRATOR
WINCHESTER, MASS., U.S.A.
SERIAL NO. 1
FINE TUNING
5MC/S
10MC/S
R-F INPUT
GAIN
SPK VOL
NORMAL
440~
4000~
BEAT CARRIER
OUTPUT
AUDIO OUTPUT

I DESCRIPTION

1. PURPOSE:

The Model RH-10 WWV Standard Frequency Calibrator is a special radio receiver designed for the reception of standard radio frequencies emanating from Station WWV operated by the United States Bureau of Standards. Audio filters incorporated within the set enable the operator to make use of the modulation frequencies of 440 and 4000 cycles per second. The calibrator will help perform the following functions:

a. Checking the pitch of musical instruments. 440 cycles per second is A4 (A above middle C) on the "Equal Tempered Chromatic Scale" which was adopted by Music Industries Chamber of Commerce of the United States in 1925. Accuracy is 1 part in 10,000,000.

b. Checking clocks and timing devices. The time pulses of WWV are one second apart and accurate to 10 microseconds. Intervals of five minutes or longer are accurate to 1 part in 10,000,000.

c. Checking or setting audio frequencies. 440 and 4000 cycles per second signals are accurate to 1 part in 10,000,000.

d. Checking or setting RF frequencies or the harmonics to the carrier frequencies of WWV. Accuracy is 1 part in 10,000,000.

2. CHARACTERISTICS:

a. Power input: 90 volt-amperes at 115 volts, 60 cycle, single phase.

b. RF sensitivity: Less than 0.5 microvolts.

c. Selectivity: Minus 10 db at ±5 KC.

d. Image rejection ratio: Minus 50 db.

e. Frequency: Preset at 5 and 10 megacycles per second. (On special order, preset frequencies of 2.5 and 5 megacycles per second or 10 and 15 megacycles per second may be had.) Model RH-10 tunes 5 and 10 megacycles per second. Model RH-10A tunes 2.5 and 5 megacycles per second. Model RH-10B tunes 10 and 15 megacycles per second.

f. Four separate audio operations are provided.

1. "NORMAL" Set operates as a normal receiver.

2. "440" Sharp audio filter tuned at 440 CPS (-10 db at ±10% from resonance) allows reception of the 440 cycle note without interference from other modulation frequencies or noise.

3. "4000" Sharp audio filter tuned at 4000 CPS (-10 db at ±10% from resonance) allows reception of the 4000 cycle note without interference from other modulation frequencies or noise.

4. "BEAT CARRIER" Low pass filter (-10 db at 400 CPS) allows beat note of unknown frequency and WWV standard frequency to be observed on the cathode ray tuning eye.

g. Audio output voltages are adjustable from 0 to 5 volts at approximately 250 ohm output impedance.

h. Tube complement:

5Y3	- Power Rectifier
6SA7	- Mixer
6SJ7	- Selective Audio Amplifier
6SK7	- RF Amplifier
6SK7	- IF Amplifier
6SK7	- IF Amplifier
6SN7	- Speaker Output and Cathode Follower
6J5	- Local Oscillator
6U5	- Cathode Ray Tuning Eye
6SQ7	- Detector and Audio Amplifier
OD3/VR150	- Voltage Regulator

3. CONSTRUCTION:

The RH-10 is fitted with standard 19" X 8-3/4" aluminum rack panel. All controls necessary for normal use are mounted on the front panel. Preset controls and trimmers are easily accessible on the chassis and require no special tools for alignment.

The RH-10 is supplied either in a steel cabinet with carrying handles or in a steel dust cover for rack mounting.

4. STANDARD FREQUENCY BROADCAST OF RADIO STATION WWV:

The National Bureau of Standards provides a 24 hour broadcast service of standard frequencies from its radio station WWV at Beltsville, Maryland. Standard radio frequencies, standard audio frequencies, standard time intervals, standard musical pitch, and time announcements are available at all times. WWV's frequencies and time intervals are controlled by a 100 KC per second standard frequency piezo-crystal oscillator. The average frequency value is based upon and agrees with the average United States Naval Observatory time signals. All standards of frequency are ultimately referred to the period of rotation of the earth; this fundamental source might be referred to as one cycle per day or one cycle per 86,400 seconds.

The accuracy of all frequencies, radio and audio, as transmitted is better than one part in 10,000,000. Atmospheric conditions may cause slight fluctuations in frequencies as received, but the average

frequency is as accurate as that transmitted. The time intervals marked by pulses at every second are accurate to 10 microseconds. Time intervals of five minutes or longer are accurate to 1 part in 10,000,000.

WWV SCHEDULE, as of July 1, 1946

2.5 MC - 7:00 p.m. to 9:00 a.m. EST (2400 to 1400 GWT)
Audio modulation: 440 CPS.

5.0 MC - Continuous
Audio modulation: (Only on hours indicated)
440 and 4000 CPS, 7:00 a.m. to 7:00 p.m. EST
440 CPS, 7:00 p.m. to 7:00 a.m. EST.

10.0 MC - Continuous
Audio modulation: 440 and 4000 CPS.

15.0 MC - Continuous
Audio modulation: 440 and 4000 CPS.

A 0.005 second pulse may be heard at every second except at the fifty-ninth second of each minute. Audio frequencies are interrupted precisely on the hour and each five minutes thereafter, resuming after an interval of precisely one minute. During the one minute interval Eastern Standard Time is given in telegraphic code. Voice announcements are made at the hour and half hour.

II INSTALLATION AND OPERATION

1. INSTALLATION:
The equipment is ready for operation upon unpacking. Connect the line cord to the 105 to 125 volts 50 or 60 cycle power line. Antenna connections are available on the back. Either an open wire or doublet antenna may be used. In favorable locations a short wire (20 feet) will often provide sufficient reception.

   a. Open wire antenna: The antenna should be cut for resonance at the lower of the two frequencies for which the receiver is designed. Tie one antenna terminal to the chassis. The chassis should be grounded.

   b. Doublet antenna: The antenna should be cut for resonance at the lower frequency. The chassis should be grounded to earth.

2. OPERATION CONTROLS:
   a. "GAIN" Clockwise rotation increases the gain of the entire audio system, i.e., audio output increases and speaker volume increases. It is always wise to use as low a "GAIN" setting as possible.

b. "SPK. VOL." Clockwise rotation increases the loud speaker output.

c. "NORMAL", "440", "4000", "BEAT CARRIER" Switch settings determine the receiver operation.

1. "NORMAL" In every respect the RH-10 operates as a normal receiver. The closing of the tuning eye indicates proper tuning of the receiver to the received signal.

2. "440" A highly selective audio filter allows only the 440 cycle notes to pass through the audio system.

3. "4000" A highly selective audio filter allows only the 4000 cycle notes to pass through the audio system.

4. "BEAT CARRIER" A low pass filter allows only notes below 400 cycles to pass. The tuning eye is connected to the audio output so that one may easily beat an external signal to WWV's carrier to a fraction of a cycle per second.

d. "OUTPUT" Clockwise rotation increases the audio output at the panel connector marked "AUDIO OUTPUT".

e. "5 MC" and "10 MC"

1. "5 MC" The calibrator is tuned to the 5 megacycle per second carrier of radio station WWV.

2. "10 MC" The calibrator is tuned to the 10 megacycle per second carrier of radio station WWV.

NOTE: If the switch is marked with 2.5 MC or 15 MC, the calibrator is tuned to these carriers in the respective positions.

f. "FINE TUNING" This control tunes the receiver local oscillator on either band. Adjust tuning for minimum opening of tuning eye.

3. CONNECTORS:

a. "RF INPUT" Unknown signals or their harmonics may be introduced here to be compared with WWV's carrier.

b. "AUDIO OUTPUT" Audio output may be obtained here for viewing on an oscilloscope. The type of output is determined by

the "NORMAL", "440", "4000", and "BEAT CARRIER" switch. Output level is adjustable by the "OUTPUT" control.

4. OPERATION PRECAUTIONS:

When RF signals are exceptionally strong, the "GAIN" control should always be used in the lowest setting. First set the "SPK. VOL." control to 3/4 of maximu, then adjust the "GAIN" control to give the required volume for comfortable listening. This is done to prevent distortion by overloading of the first audio stage.

5. OPERATION:

a. Preliminary:

1. Turn on set by turning "GAIN" control clockwise.

2. Select the desired carrier frequency of either 5 or 10 megacycles per second.

3. Set operation switch on "NORMAL".

4. Set "SPK. VOL." control to 3/4 maximum.

5. Advance "GAIN" control until noise is heard.

6. Tune "TUNING" control until the signals of WWV are heard. WWV may be identified by the tone modulation and by the one second interval pulses. (See I-4). Adjust for minimum opening of the tuning eye.

7. Reset "GAIN" control for desired level of volume from speaker.

The calibrator is now functioning as a normal receiver. In the following operations it should be remembered that the signal obtained at the "AUDIO OUTPUT" connector also emanates from the speaker as an audible sound.

b. Audio frequency measurements:

By utilizing the modulation frequencies of WWV one can compare or measure audio frequencies which are in fractional harmonic, subharmonic, or harmonic relation. This can be better expressed by the equation:

$f = \frac{K1}{K2}\ 440$ or $f = \frac{K1}{K2}\ 4000$ where K1 and K2 are integers.

1. Connect the RH-10 audio output to the horizontal amplifier of the oscilloscope.

2. Connect the test audio frequency to the vertical amplifier.

3. Turn operation switch to "440" or "4000" for either audio frequency output. Amplitude is controlled by the "OUTPUT" control.

A block diagram of the set-up required is shown in Figure 2.

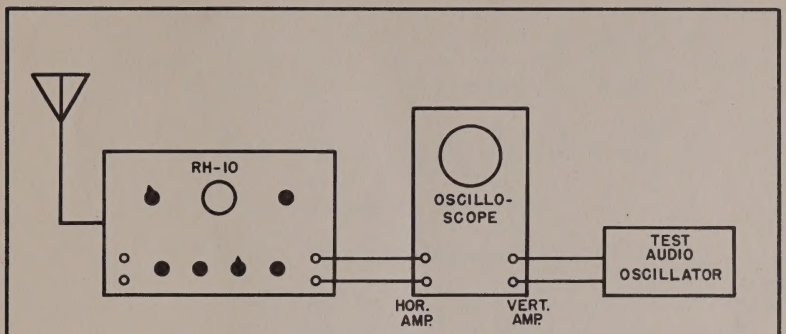
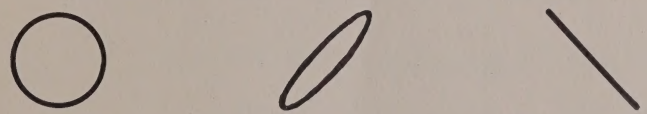
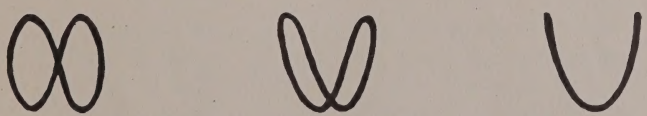


FIGURE 2:
BLOCK DIAGRAM FOR MEASUREMENT OF AUDIO FREQS.

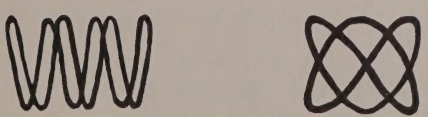
By observing the Lissajous figure produced on the screen one can immediately determine the frequency relations. A few examples are found in Figure 3.



RATIO 1:1 WITH VARIOUS PHASE RELATIONS.



RATIO 2:1 WITH VARIOUS PHASE RELATIONS.



RATIO 6:1 RATIO 3:2

FIGURE 3:
TYPICAL LISSAJOUS FIGURES

When the resulting pattern remains stationary, the ratio relations are exact. If the pattern drifts slowly, the ratio relation is not exact but slightly higher or lower. By measuring the time required for a particular point on the pattern to travel one complete cycle along the horizontal axis, the exact ratio can be determined. The test frequency is as follows:

$$f = R\left[Fm \pm \frac{Fm}{t\,Fm \mp 1}\right] \cong R\left[Fm \pm \frac{1}{t}\right]$$

where f = test audio frequency

Fm = WWV's modulation frequency

t = time in seconds for a particular point to complete one cycle along the horizontal axis.

R = Ratio relation determined from Lissajous figure $\cong$ f/Fm.

To determine whether the test frequency is higher or lower, the test frequency or its phase can be shifted slightly to note the direction of drift.

EXAMPLE: Using the modulation frequency of 440 CPS, the ratio relation was found to be 1:4. The pattern drifted slowly requiring 500 seconds to complete a cycle along the horizontal axis. The test frequency is as follows:

$$f = 1/4\left(440 \pm \frac{440}{550 \times 440 \mp 1}\right) \cong 1/4\left(440 \pm \frac{1}{500}\right)$$

$$= 1/4(440 \pm .002) \text{ or } 110 \pm .0005 \text{ CPS.}$$

The correction is plus or minus depending upon the direction of drift.

e. Standard time interval measurements:
The accuracy of the time interval marked by a pulse every second as transmitted by WWV is better than 10 microseconds. For intervals of 1, 4, or 5 minutes the accuracy is better than 1 part in 10,000,000. With appropriate chronograph or oscillographic recording equipment, the second pulses can be used to measure short or long time intervals. Second pulses may also be used to control a frequency source; whether it be an electrical oscillating system or a mechanical vibration system.

Measurements of low frequencies, 1 to 200 CPS can be accurately made using the second pulses. For example, assume that a test frequency of approximately 100 cycles is applied to the horizontal plates of an oscilloscope and the WWV second pulse is applied to the vertical

plates. If the pulse travels along the screen and returns to its original position after three hours or 1,080,000 cycles later, the frequency is, therefore, accurate to approximately 1 part in 1,000,000.

In using the second pulses, the RH-10 may be set to "NORMAL" or "BEAT CARRIER" operation.

d. Standard musical pitch
The modulation frequency of 440 CPS corresponds to pitch A above middle C (or A4) in the "Equal Tempered Chromatic Scale" as adopted by the American Standards Association in 1936.

To utilize the pitch A4 to its fullest extent, use the RH-10 in the "440" position.

e. Adjusting an external RF signal to the WWV carrier:
Signals which are submultiple harmonics of any of WWV's carriers may be measured to a high degree of precision. The method consists of obtaining a beat note between a harmonic of the signal under test and one of WWV's frequencies.

1. Connect the external signal to the "RF INPUT" connector on the front panel. The amplitude of the signal should be adjusted to approximately the same level as the WWV carrier for best results. Usually a loosely coupled link to the external oscillator will give sufficient signal strength. If external signals are strong enough, a short length of wire connected to the "RF INPUT" connector or no connection at all will provide enough pickup.

2. Turn operation switch to "BEAT CARRIER" position. If the external frequency or its harmonic is within 400 cycles of the WWV carrier, the beat note will be heard. As the signal frequency or its harmonic frequency approaches the WWV carrier, the beat note will decrease in frequency. When the tuning eye opens and closes slowly the two frequencies are within a few cycles per second of each other. Finally, when the eye remains open the two frequencies should be identical within 1 part in 5,000,000.

f. Comparing an external RF signal to the WWV carrier:
In the study of oscillator drifts this method is particularly useful.

1. Connect the signal pickup as in section "e-1".

2. Connect the "AUDIO OUTPUT" to the vertical plates of an oscilloscope, and connect an audio oscillator to the horizontal plates.

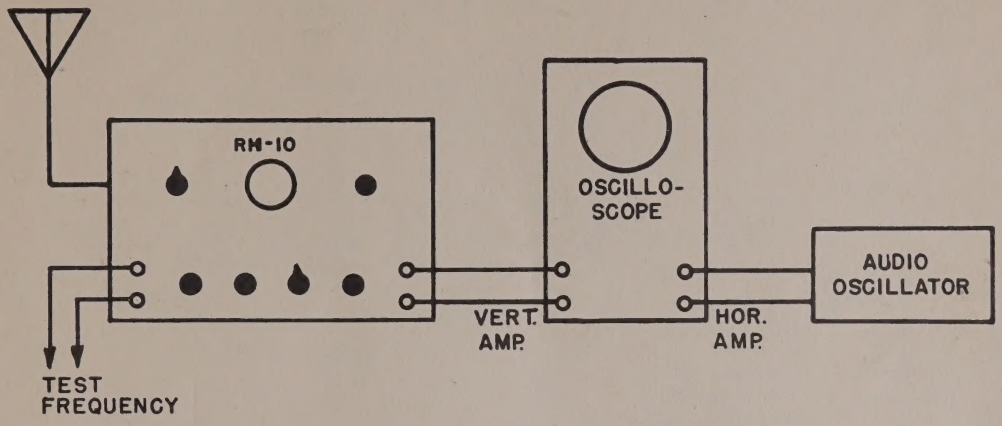


FIGURE 4:
R F FREQUENCY COMPARISON WITH W.W.V.

3. If the beat frequency should be below 400 cycles, use the "BEAT CARRIER" position of the operation switch. If it is higher than 400 cycles, use the "NORMAL" position. In any event, the beat note will appear on the oscilloscope screen. The Lissajous pattern may be adjusted by the audio oscillator until an ellipse or circle is seen. The audio oscillator dial will give the beat frequency.

   If the test frequency changes due to drifting or other causes, it will be necessary to reset the audio oscillator to regain the stationary ellipse or circle pattern. The number of cycles shift needed on the audio oscillator is a direct measure of the shift of the test frequency at the WWV frequency used. If a harmonic of the test frequency is employed, the observed shift must be divided by the number of the harmonic used to determine the actual shift at the fundamental frequency.

   NOTE: In using the receiver in the "NORMAL" position it is important to make sure that measurement is not made on the side band frequencies caused by the 440 or 4000 cycle modulating frequencies. This can be checked when the WWV modulating frequencies are turned off for one minute at five minute intervals.

CAUTION

III FUNCTIONING OF PARTS

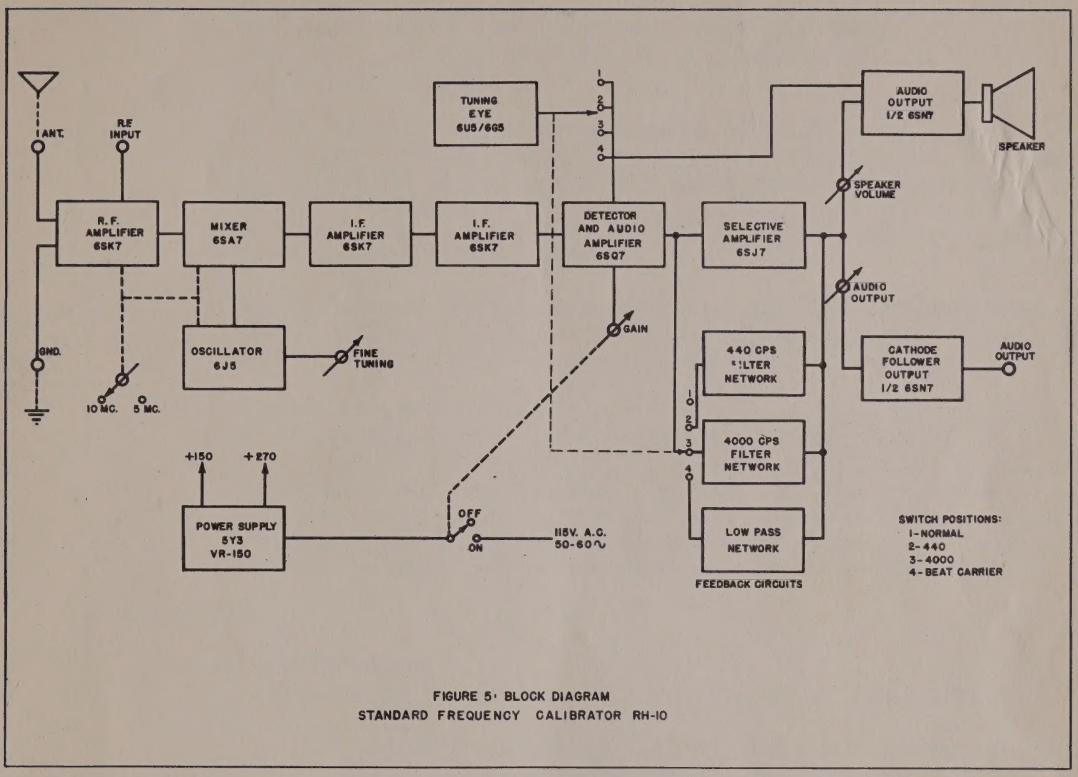


FIGURE 5. BLOCK DIAGRAM
STANDARD FREQUENCY CALIBRATOR RH-10

1. CIRCUIT AND DESIGN NOTES:

The receiver consists of a RF amplifier (6SK7), mixer (6SA7), oscillator (6J5), IF amplifier (6SK7), diode detector and audio amplifier (6SQ7). The functions are all straightforward as in the usual communication receiver. The higher frequency channel is pretuned by the permeability tuned coil. The lower frequency is pretuned by a trimmer condenser. Fine tuning is accomplished by a 3.5-7 mmf. trimmer in the local oscillator circuit. Voltage regulation is provided for the local oscillator to insure frequency stability.

The audio output is fed to an audio amplifier (6SJ7) which can function as a normal amplifier, as a selective amplifier, or as a low pass amplifier.

In the selective amplifier position a twin tee feedback network is connected between the plate and grid of the 6SJ7 tube such that all except the wanted frequencies are degenerated. Frequencies at 10% off resonance are attenuated approximately 10 decibels. Selective tunings are provided for 440 and 4000 cycles per second at the respective switch positions.

In the low pass position frequencies higher than 400 CPS are bypassed to ground. This was done so that the modulating frequencies do not interfere with measurements made with the carrier.

A power output amplifier (1/2 6SN7) drives a three inch permanent magnet dynamic speaker. The speaker should provide more than ample volume for all laboratory use. A separate "SPK. VOL." control enables variation of the output volume from zero to maximum. Low-impedance (250 ohm) audio output is provided by a cathode follower (1/2 6SN7). A separate output control enables one to vary the output from zero to maximum. Maximum voltage output is approximately five volts.

IV MAINTENANCE

1. GENERAL MAINTENANCE:

a. Replacement of tubes may require retuning of components.

1. V-1 (6SK7) Retuning of L-1 and C-4 may be necessary. This can be done by listening to WWV.

2. V-2 (6SA7) Retuning of L-2, C-9, and transformer T-1 may be necessary.

3. V-3 (6J5) No retuning is usually necessary.

4. V-4 (6SK7) Retuning of T-1 and T-2 may be necessary.

5. V-5 (6SK7) Retuning of T-2 and T-3 may be necessary.

6. V-6 (6SQ7) Retuning of T-3 may be necessary.

7. V-7 (6SJ7), V-8 (6SN7), V-9 (6U5/6G5), V-10 (OD3/VR150), V-11 (5Y3) No adjustments are necessary.

b. Replacement of bandswitch or any one wafer can be more easily done by first removing the drive shaft coupling.

c. No fuses or circuit breakers are provided with the set.

2. CIRCUIT ADJUSTMENTS:

a. Aligning the IF amplifier: (GAIN)

1. Place a high resistance DC voltmeter (0-10 volts) across R-18.

2. Connect a RF signal generator, 456 KC, to the grid of V-5.

3. Adjust the permeability tuning slugs of IF transformer T-3 for maximum meter deflection.

4. Connect the 456 KC signal to the grid of V-4.

5. Adjust the permeability tuning slugs of IF transformer T-2 for maximum meter deflection. Reduce the 456 KC signal strength, if necessary, to keep the meter on scale.

6. Connect the 456 KC signal to the grid of V-2.

7. Adjust the permeability tuning slugs of IF transformer T-1 for maximum meter deflection. Reduce the 456 KC signal, if necessary.

b. Aligning the RF stages:
NOTE: In the following procedures always adjust the test signal strength to keep the meter needle on scale.

1. Place a high resistance DC voltmeter (0-20 volts) across R-18.

2. Connect a signal generator to the grid of V-2 and set the test signal to the higher of the two pretuned frequencies.

3. Set the panel "TUNING" condenser to midrange.

4. Adjust the permeability tuning slug of L-3 to give maximum meter deflection.

5. Connect the test signal to the antenna terminals.

6. Adjust the permeability tuning slugs of L-1 and L-2 for maximum meter deflection.

7. Again connect the test signal to the grid of V-2 and set the test signal to the lower frequency.

8. Adjust C-14 for maximum meter deflection.

9. Connect the test signal to the antenna terminal.

10. Adjust C-9 and C-4 for maximum meter deflection.

c. Aligning the selective amplifier:
The controls of the selective amplifier are aligned at the factory and are locked in place. No attempt should be made to retune them unless the amplifier absolutely refuses to function. Improper alignment may cause the circuit to be too selective and may even lead to oscillation or, in the other extreme, the selectivity may be lost. In the following procedure either an audio test signal or the signals of WWV may be used:

1. Tune the calibrator to any carrier frequency of WWV or connect an audio test signal across R-18.

2. At the 440 switch position, turn potentiometer R-28 counter-clockwise. A howl should be heard in the speaker. Back the control clockwise approximately 15 degrees from the point where the howl disappears.

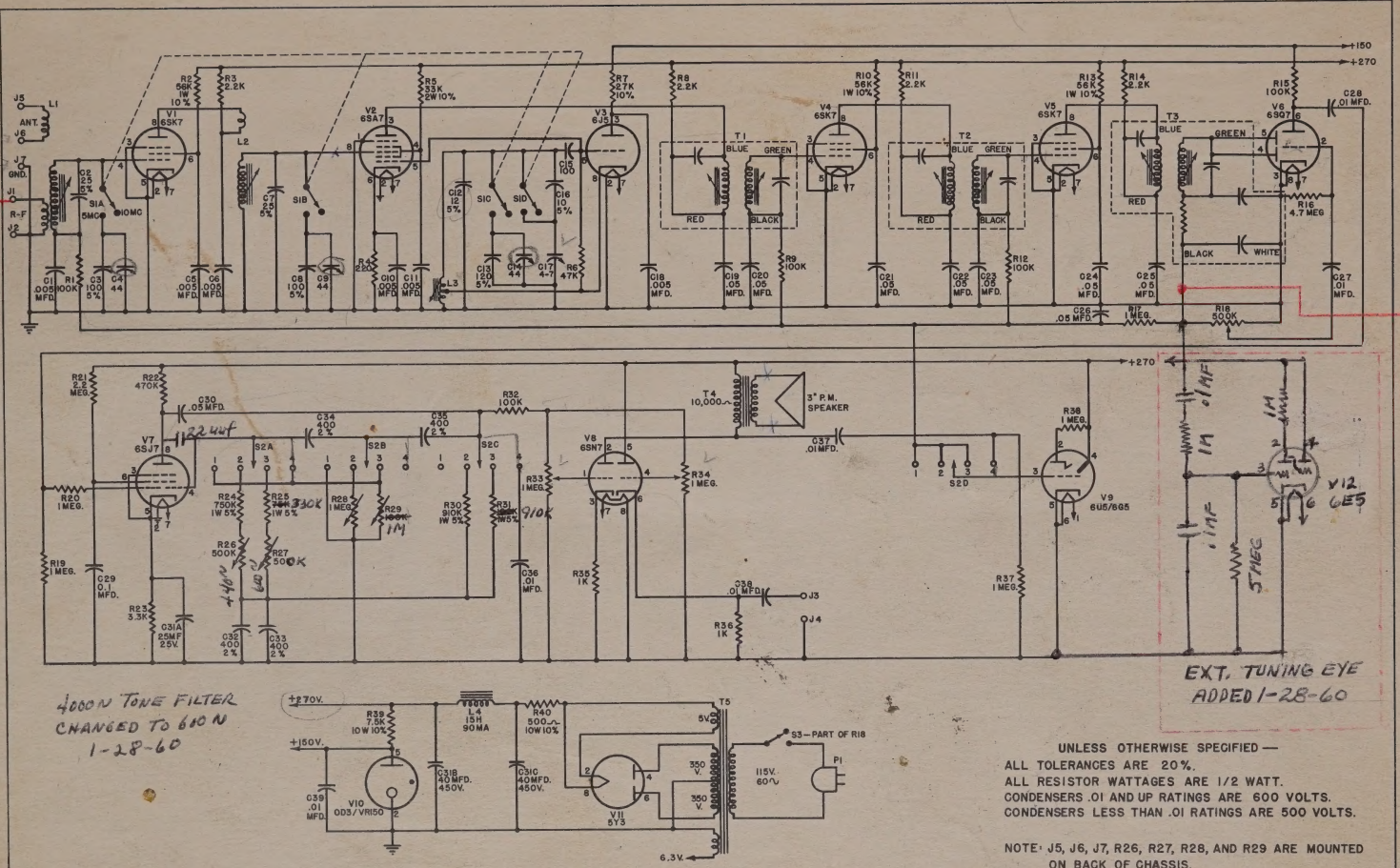
3. Adjust R-26 for maximum audio output. This can be done by ear, or by a meter or oscilloscope connected to the "AUDIO OUTPUT" terminals.

4. If higher selectivity is desired, advance control R-28 counter-clockwise by a few degrees and retune R-26. If lower selectivity is desired, turn control R-28 clockwise and retune R-26.

5. At the 4000 switch position, repeat procedure "2" on control R-29.

6. Repeat procedure "3" on control R-27. Selectivity may be altered by readjusting R-29 and R-27 respectively as in procedure "4".

3. TROUBLE SHOOTING:
The following information and data should help locate any fault. If the set refuses to receive signals when the tubes all light up, one may immediately determine whether the trouble is in the RF or audio stages by turning the "GAIN" and "SPK. VOL." control on full. If a loud rushing sound can be heard, the fault is in the RF stage. If no noise can be heard, the fault is in either the IF or audio stages.



UNLESS OTHERWISE SPECIFIED —
ALL TOLERANCES ARE 20%.
ALL RESISTOR WATTAGES ARE 1/2 WATT.
CONDENSERS .01 AND UP RATINGS ARE 600 VOLTS.
CONDENSERS LESS THAN .01 RATINGS ARE 500 VOLTS.

NOTE: J5, J6, J7, R26, R27, R28, AND R29 ARE MOUNTED ON BACK OF CHASSIS.

FIGURE:8
WWV SCHEMATIC RH-10

TUBE	PIN 1	PIN 2	PIN 3	PIN 4	PIN 5	PIN 6	PIN 7	PIN 8
V1 6SK7	0	0	0	-.5-2.4	0	105	6.3V AC	218
V2 6SA7	0	0	225	90	-2	1.9	6.3V AC	0
V3 6J5	0	0	90		-2.7		6.3V AC	0
V4 6SK7	0	0	0	-.5-2.4	0	105	6.3V AC	212
V5 6SK7	0	0	0	-.5-2.8	0	105	6.3V AC	212
V6 6SQ7	0	-.51.3	0	-.5-3	-.5-3	95 120	6.3V AC	0
V7 6SJ7	0	0	1.5	0	1.5	32	6.3V AC	60 70
V8 6SN7	0	240	378	0	240	40	6.3V AC	0
V9 6U5 Eye	0		-.528	240	0	6.3V AC		
V10 OD3/VR150		0			150			
V11 5Y3		320		340V AC		340V AC		320

Voltages are referred to the chassis with no signal input.
Voltages are DC unless marked otherwise.
Meter sensitivity: DC 20,000 ohms per volt. AC 1000 ohms per volt.

VOLTAGE READINGS OF TUBE SOCKET PINS

FIGURE 6

TUBE	PIN 1	PIN 2	PIN 3	PIN 4	PIN 5	PIN 6	PIN 7	PIN 8
V1 6SK7	0	0	0	1.6 MEG.	0	*	0	*
V2 6SA7	0	0	*	*	47K	220	0	0
V3 6J5	0	0	*		47K		0	0
V4 6SK7	0	0	0	1.6 MEG.	0	*	0	*
V5 6SK7	0	0	0	1.6 MEG.	0	*	0	*
V6 6SQ7	0	0	0	550K	550K	*	0	0
V7 6SJ7	0	0	3.3K	.4 to 1 MEG.	3.3K	*	0	*
V8 6SN7	0 to 1 MEG.	*	1K	0 to 1 MEG.	*	1K	0	0
V9 6U5	0	*	1.6 MEG.	*	0	0		
V10 OD3/VR150		0			*			
V11 5Y3		*		65		65		*

*Resistance measured depends on the leakage resistance of the filter condenser C-31 which varies from unit to unit.

DC RESISTANCE MEASUREMENT TO GROUND

FIGURE 7.